MP simulations in ILC and 650 MHz cavities

S. Kazakov

02/09/2011

Goals:

- Find proper tools /approach for MP simulation
- To understand possibility of MP in 650 MHz cavities

Code for MP simulation we have in the lab:

- **Analyst: 3D, mega-particles, simple model of emission***
- **Multipac: 2D, simple model of emission***
- **Fishpac: 2D, simple model of emission***
- **CST : 3D , PIC, "real" particles, Fuman model of emission****

*Take into account only 'true' secondary emission

** Take into account 'true', 'elastic' and 'rediffused' secondary particles

Initial situation:

Analyst
Multipac
Fishpac

- no multipactor in FNAL/JLab/ILC cavities.

CST (preliminary runs) – multipactor in all cavities.

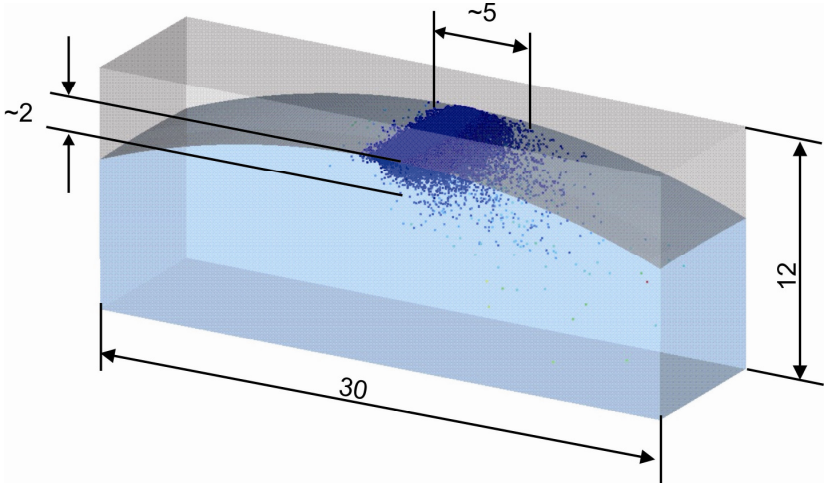
Experiment: soft multipactor in ILC cavities ~ 20-25 MV/m acc. gradient

Where is truth?

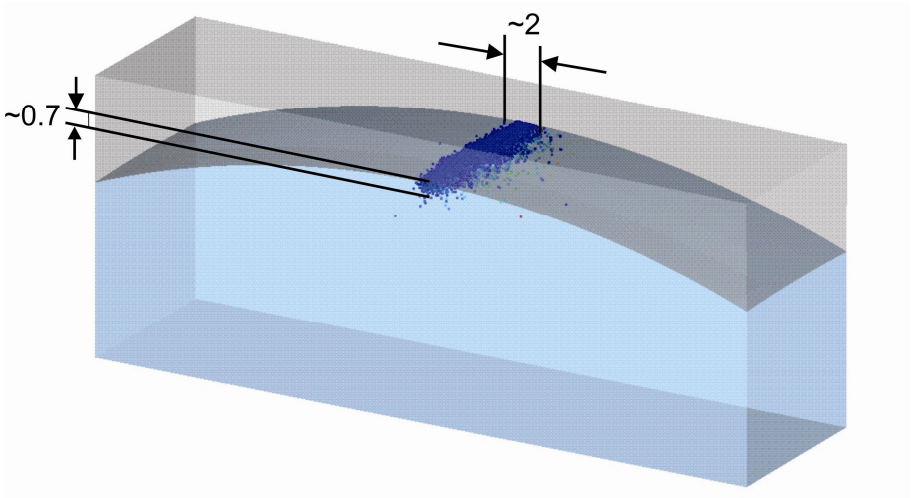
Is majority right?

CST – is most sophisticated code.
But there are some difficulties in simulations related to small sizes of multipactor area:

Typical sizes of MP areas (all sizes are in mm):



Strong MP in ILC cavity,
growth rate ~ 0.4 1/ns



Weak MP in ILC cavity,
growth rate ~ 0.0 1/ns

Cell size of mesh should be ~0.1 mm for adequate simulations.

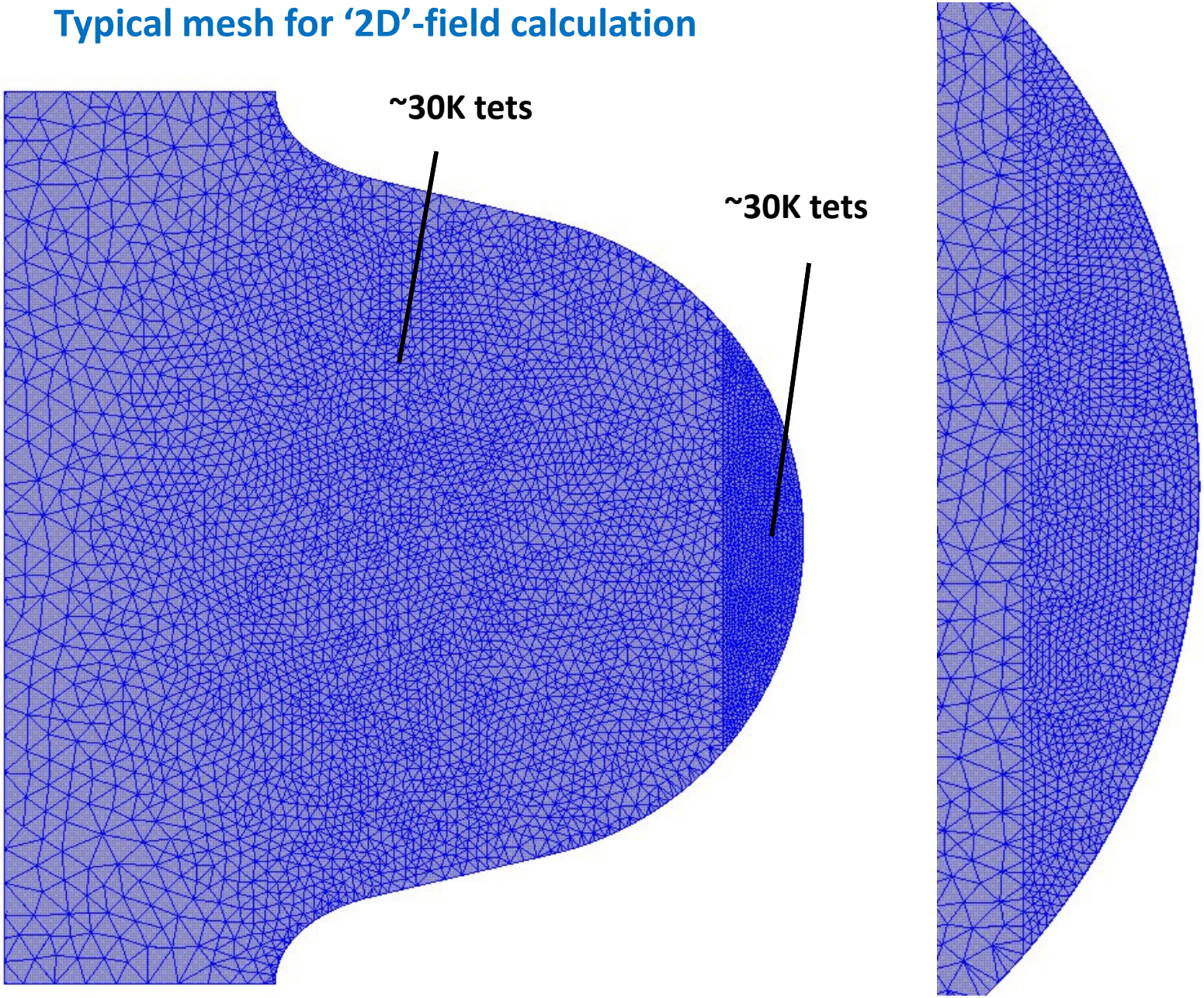
We can not simulate whole cavity. It requires ~1.E+9 cells

Procedure of simulation:

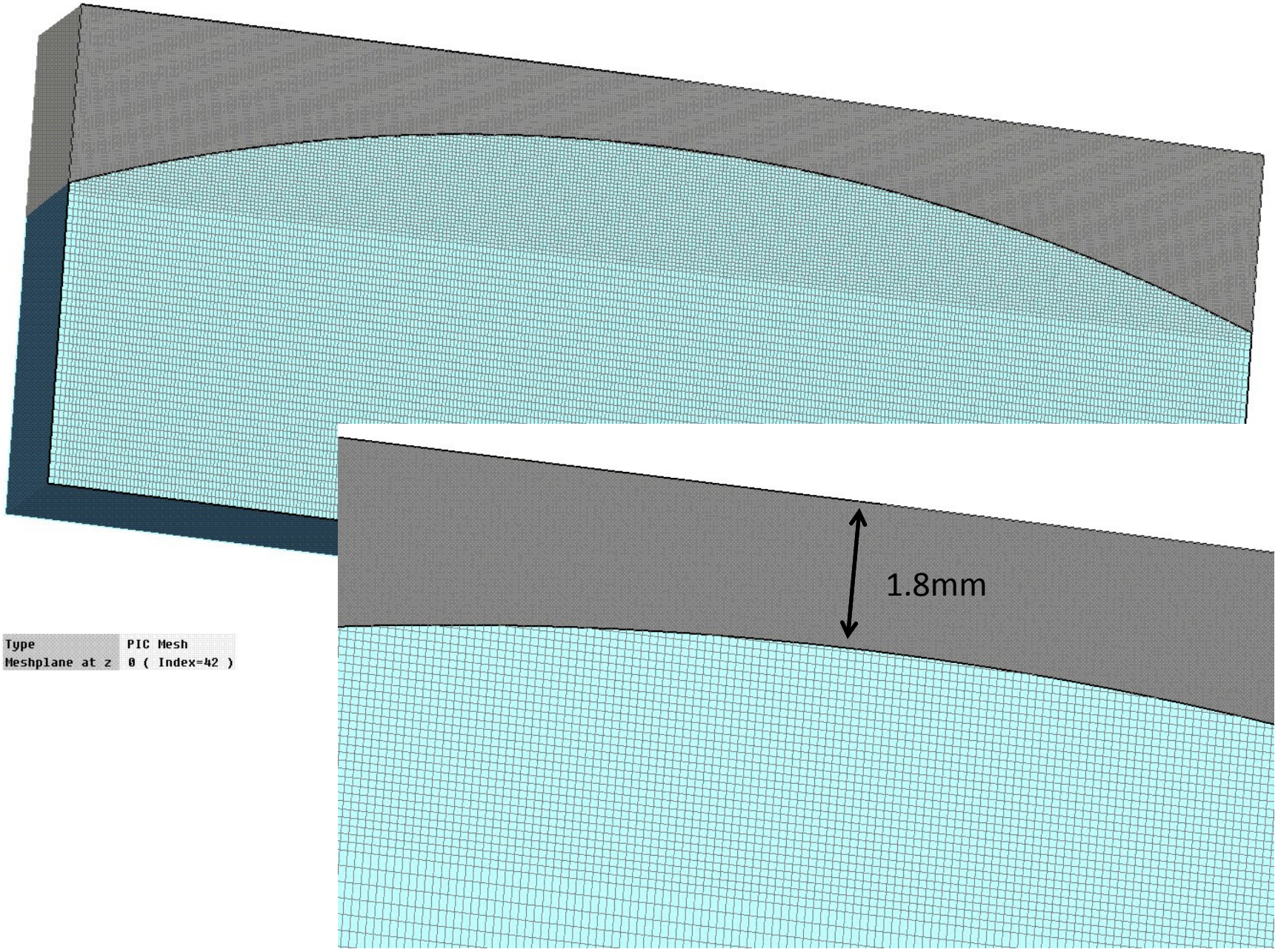
1. Calculation of field by quasi- 2D code HFSS (1^{O} sector), 2-nd order tetrahedron mesh.
2. Extracting 2D fields with 0.1mm (or less) step.
3. Creating 3D fields from 2D with step 0.1mm (or less) in volume of interest.
4. Import 3D fields into CST
5. Simulation particles motion by CST with mesh ~0.1 x 0.2 mm

Typical numbers of mesh cells of CST simulation is ~ 2E+6
Typical starting number of particles ~1-3E+4.
Typical time of simulation ~1-2 hour per variant.
Main limitation – time of calculation.

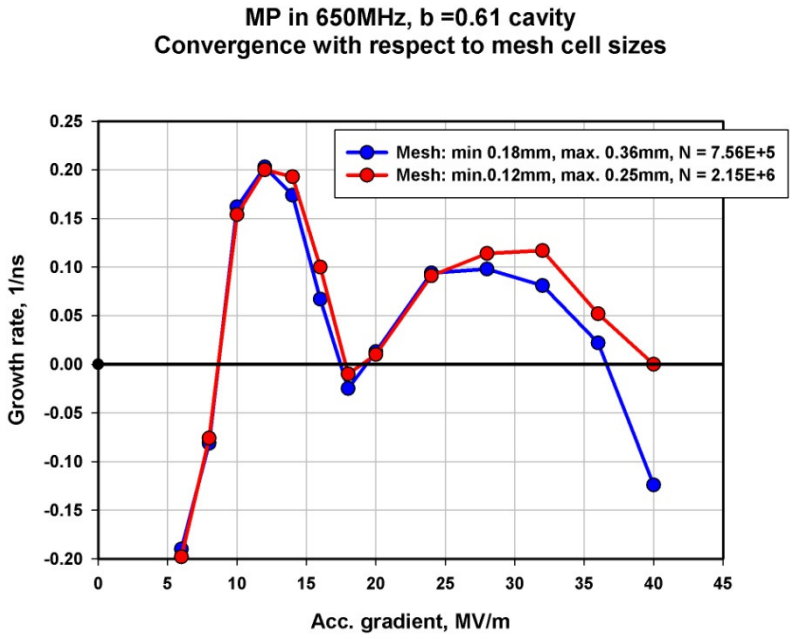
Typical mesh for ‘2D’-field calculation

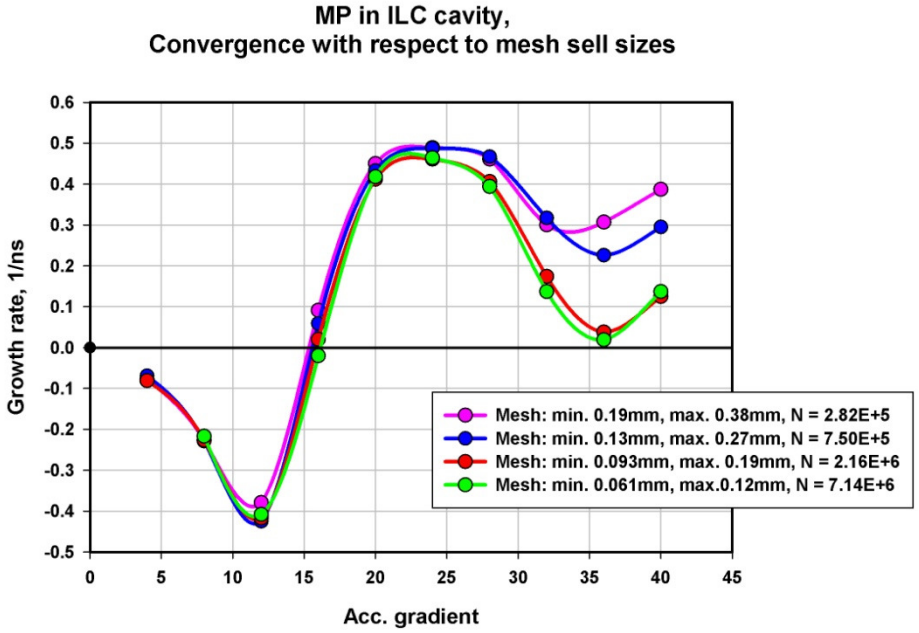


Typical CST mesh for motion simulation:

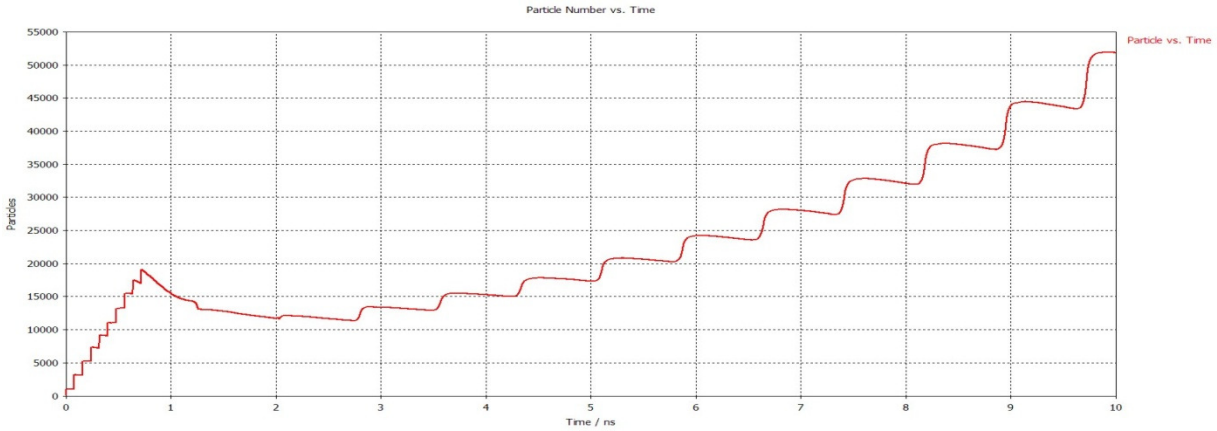


Convergence with respect to mesh sell sizes

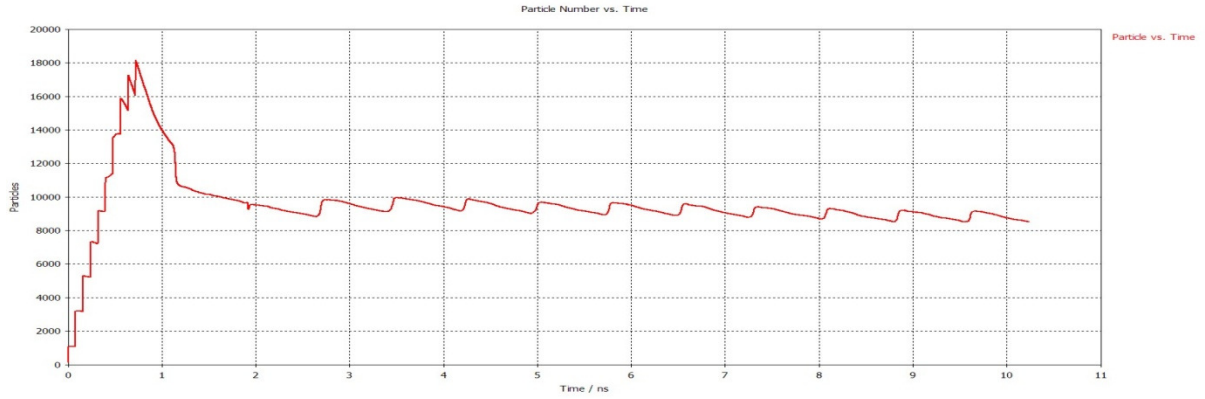




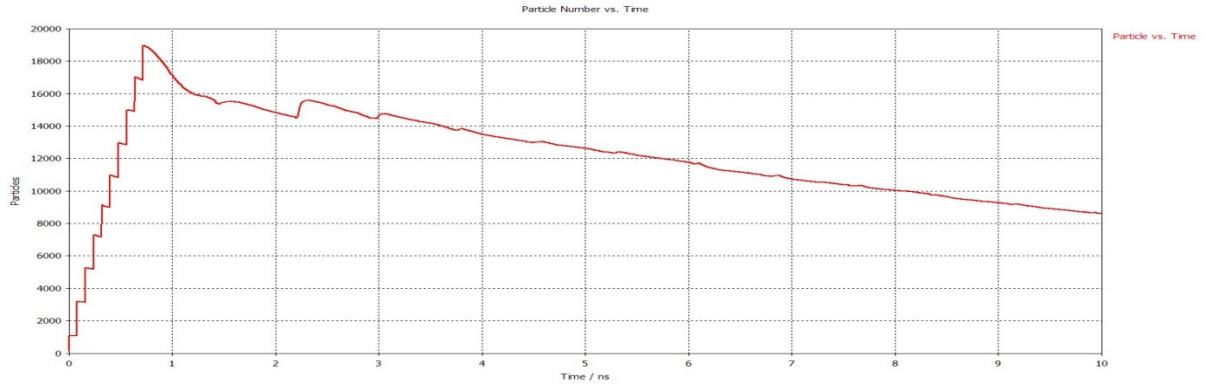
Typical behavior of particles number vs. time



G > 0



G = 0



G < 0

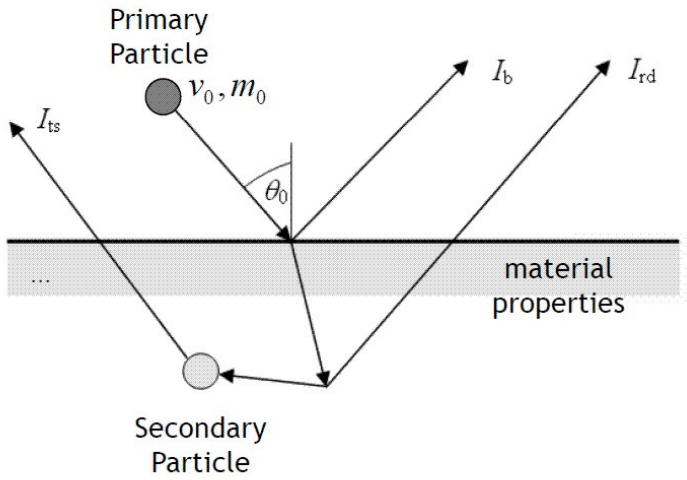
Model of material

Three types of scattering particles are taken into account in CST code:

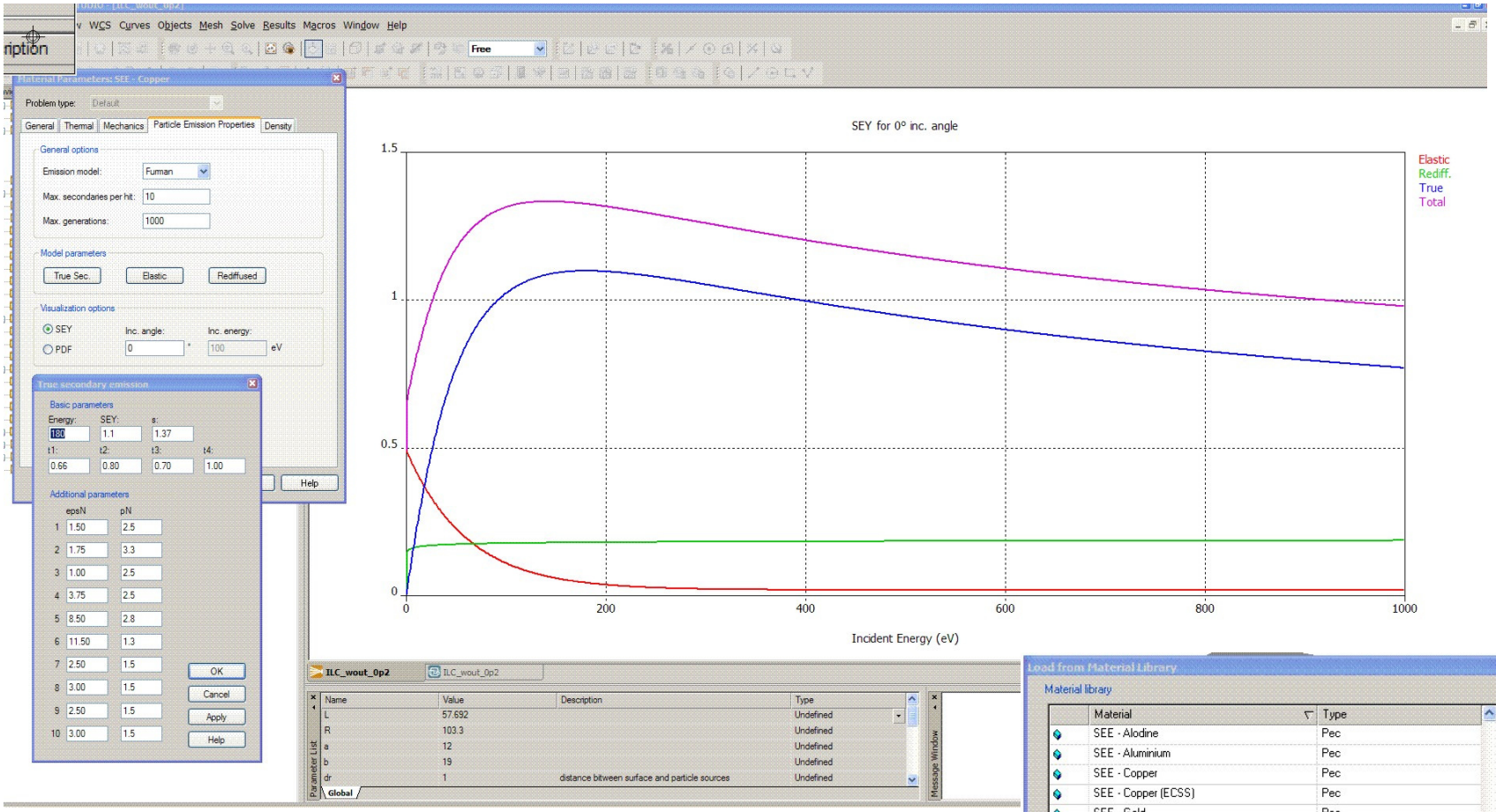
Secondary Electron Emission

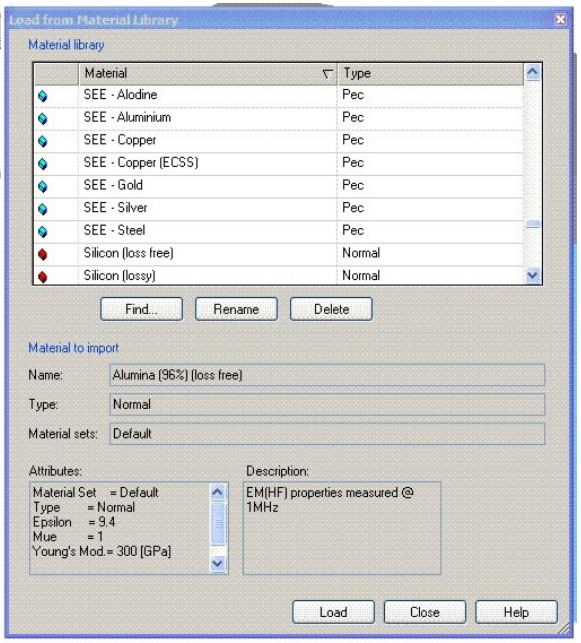
Secondary emission
[A primary particle hitting a metal surface can cause the emission of so called secondary particles]:

- Depends on the kinetic energy and material properties
- Self consistent model according to Furman
- Statistical behaviour



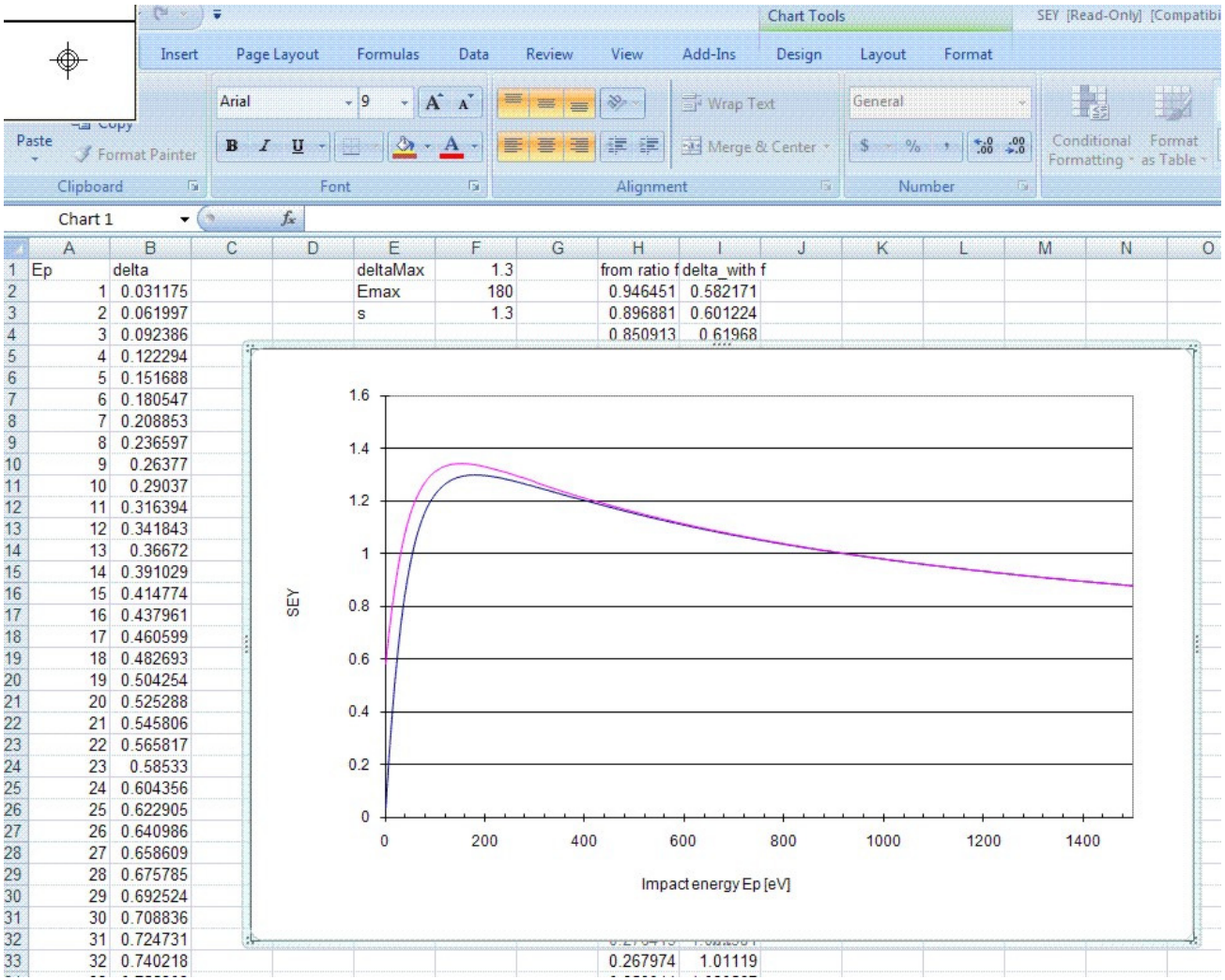
ts: true secondary electrons
b: backscattered electrons
rd: rediffused electrons





There is several materials in CST library, but there is no niobium .

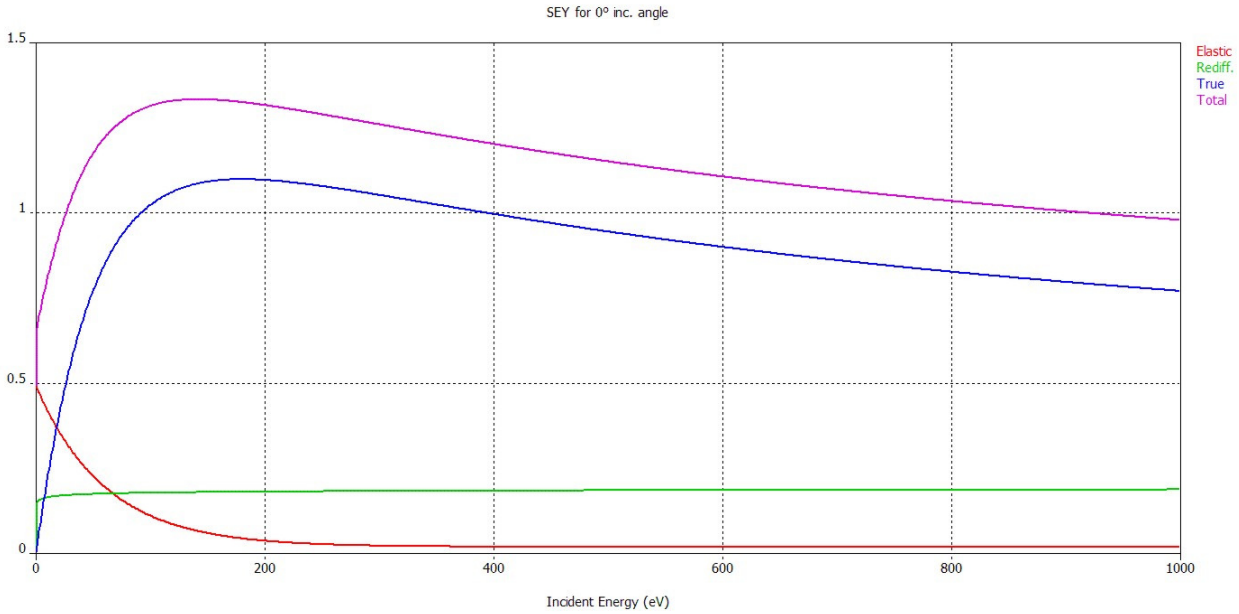
Dates from Genfa Wu were used for simulation:



Ep	delta		deltaMax	1.3		from ratio f	delta_with f
1	0.031175		Emax	180		0.946451	0.582171
2	0.061997		s	1.3		0.896881	0.601224
3	0.092386					0.850913	0.61968
4	0.122294						
5	0.151688						
6	0.180547						
7	0.208853						
8	0.236597						
9	0.26377						
10	0.29037						
11	0.316394						
12	0.341843						
13	0.36672						
14	0.391029						
15	0.414774						
16	0.437961						
17	0.460599						
18	0.482693						
19	0.504254						
20	0.525288						
21	0.545806						
22	0.565817						
23	0.58533						
24	0.604356						
25	0.622905						
26	0.640986						
27	0.658609						
28	0.675785						
29	0.692524						
30	0.708836						
31	0.724731						
32	0.740218					0.267974	1.01119

Max. SEY = 1.3, E_max = 180V, Cross 1 = 900V

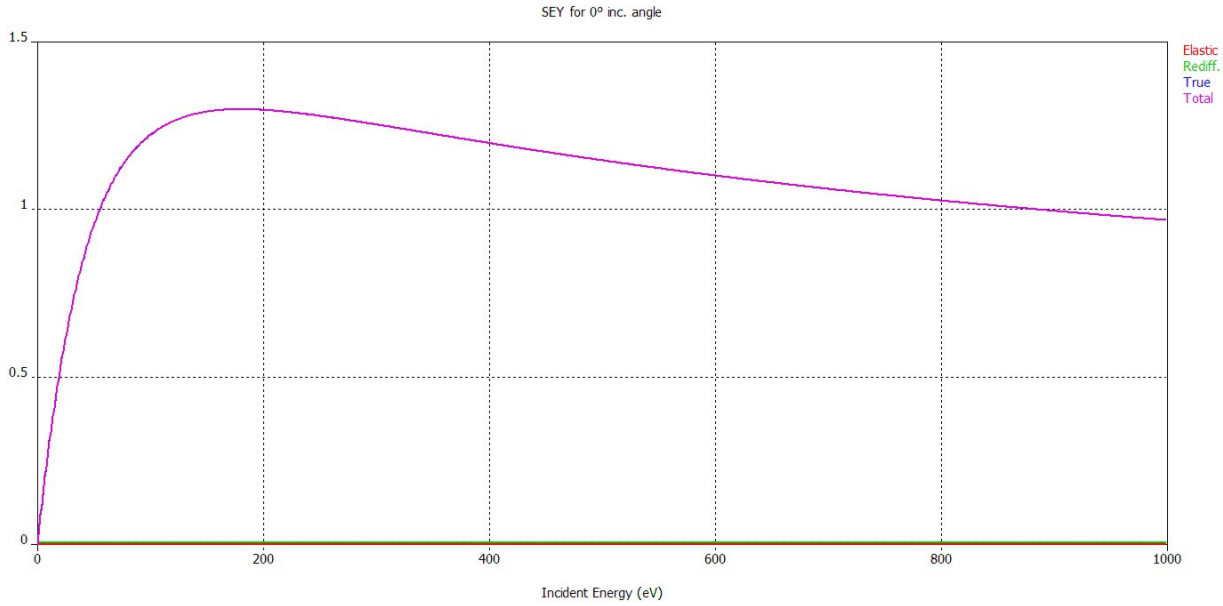
Two options were used to simulate niobium:



Option 1:

Base is copper.
Elastic and rediffused are similar to copper ones.

True secondary was modified.
Total curve matches GW curve.

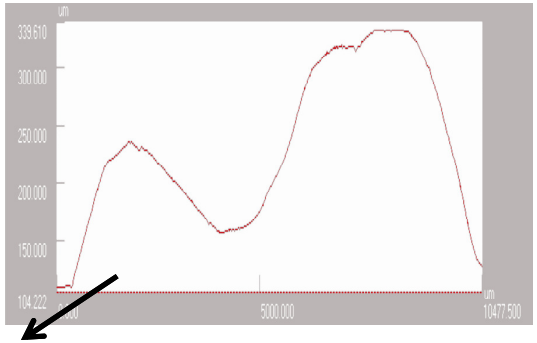


Option 2:

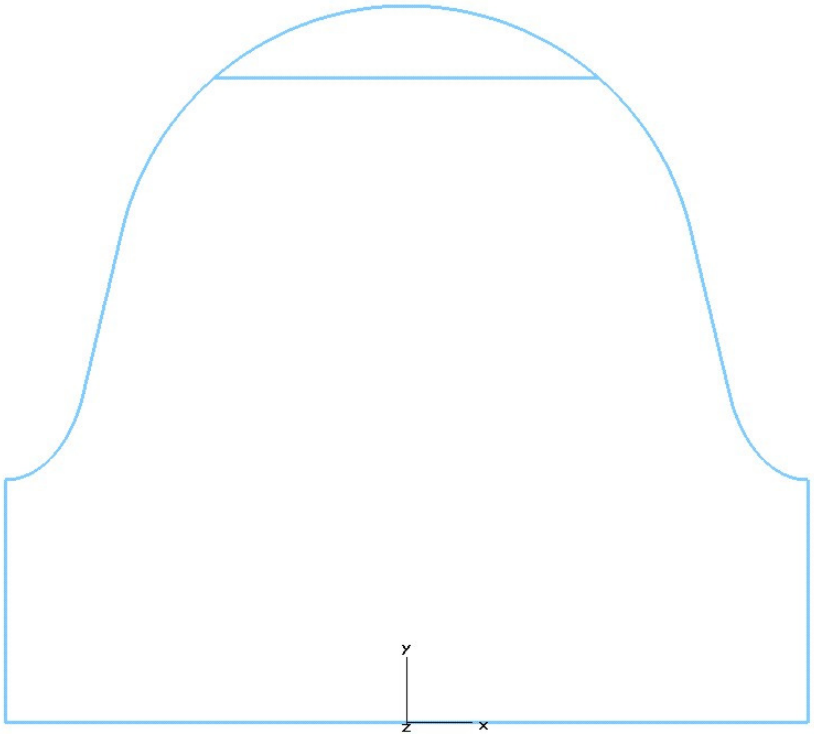
No elastic
No reduffused

True secondary curve (and total curve) matches GW curve.

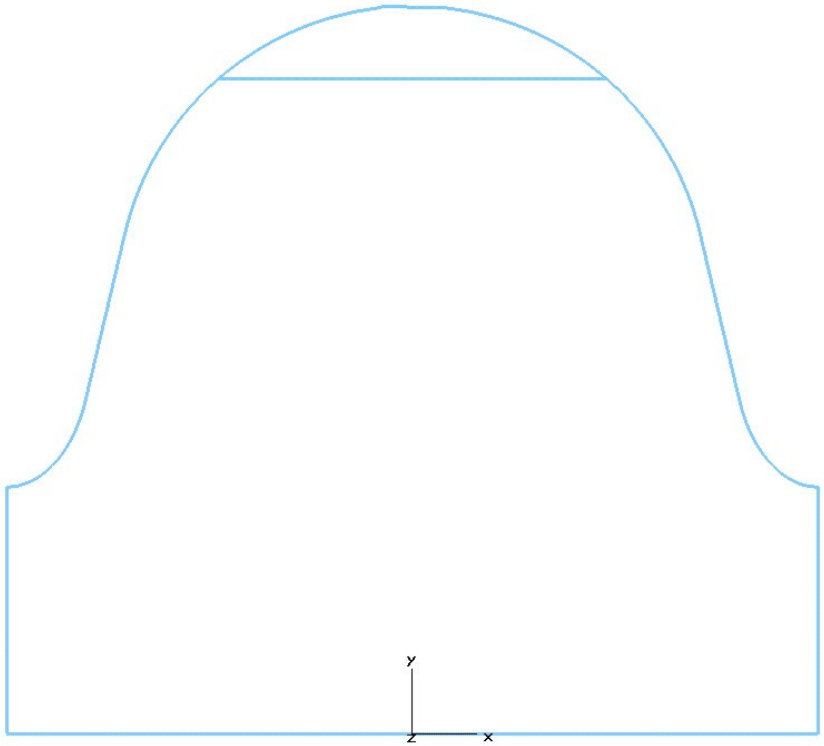
Simulations of MP in ILC cavity.



Ideal shape:

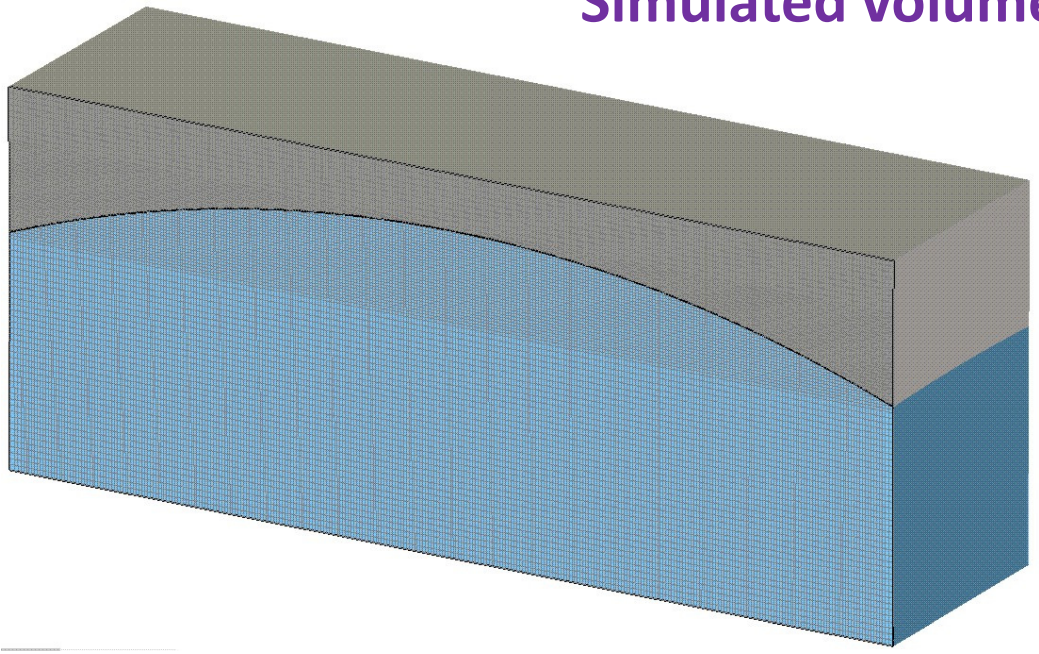


Real shape:



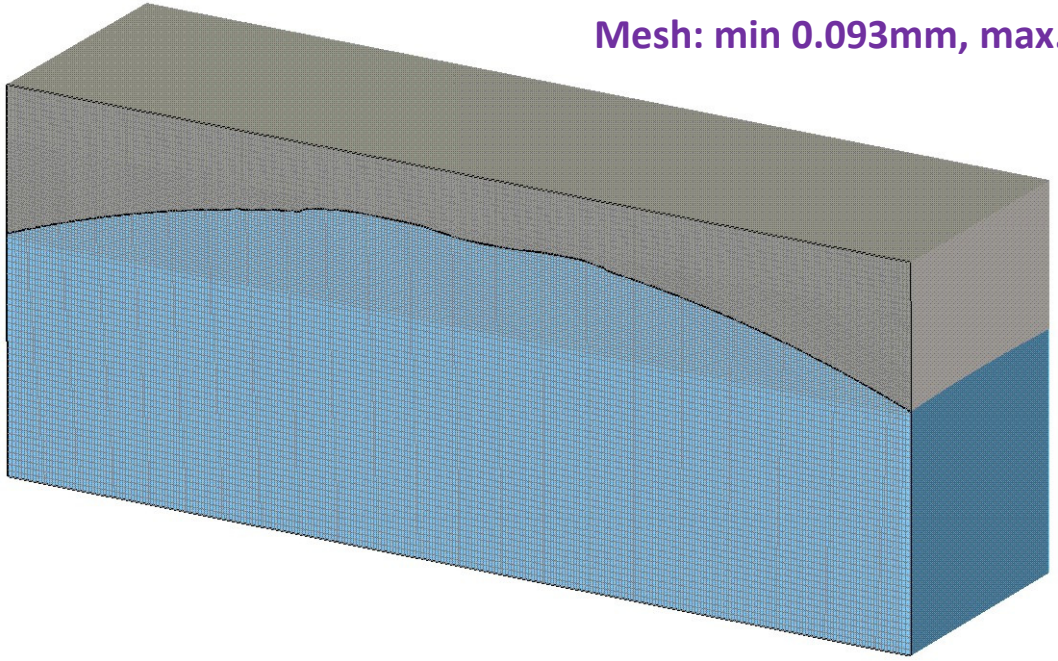
Simulated volumes and mesh

Ideal shape:

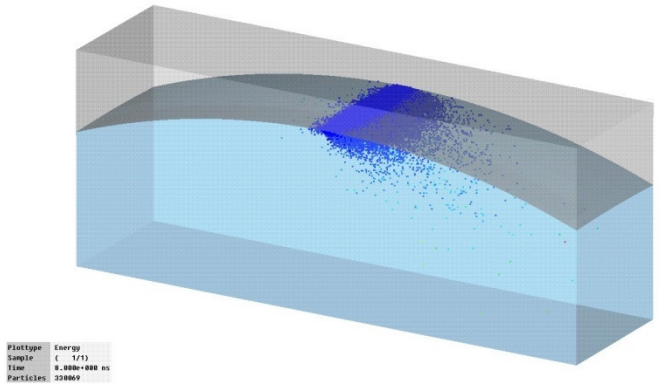


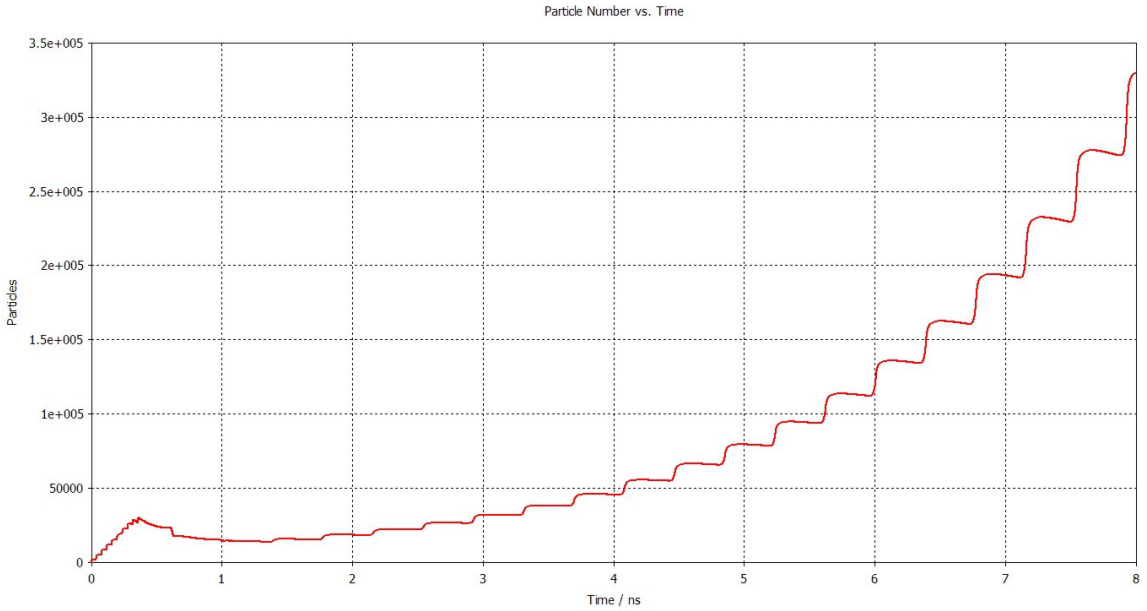
Mesh: min 0.093mm, max. 0.19 mm, N = 2.16E+6

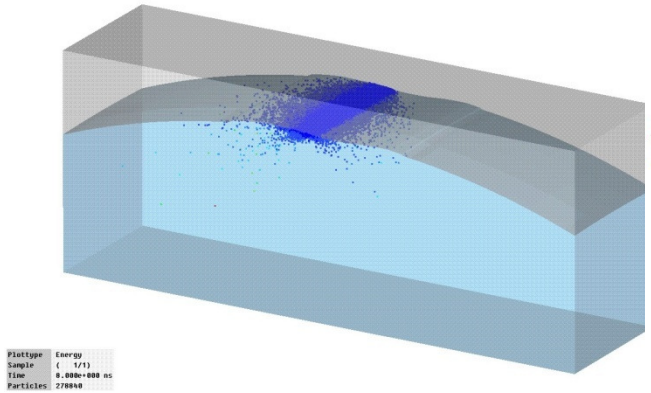
Real shape:

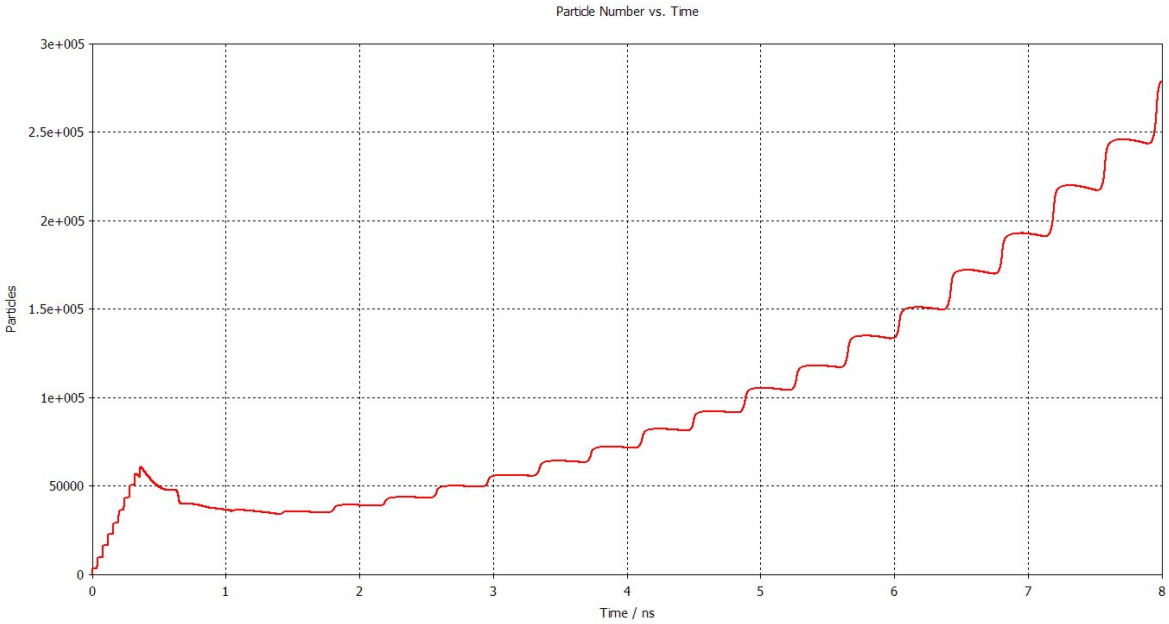


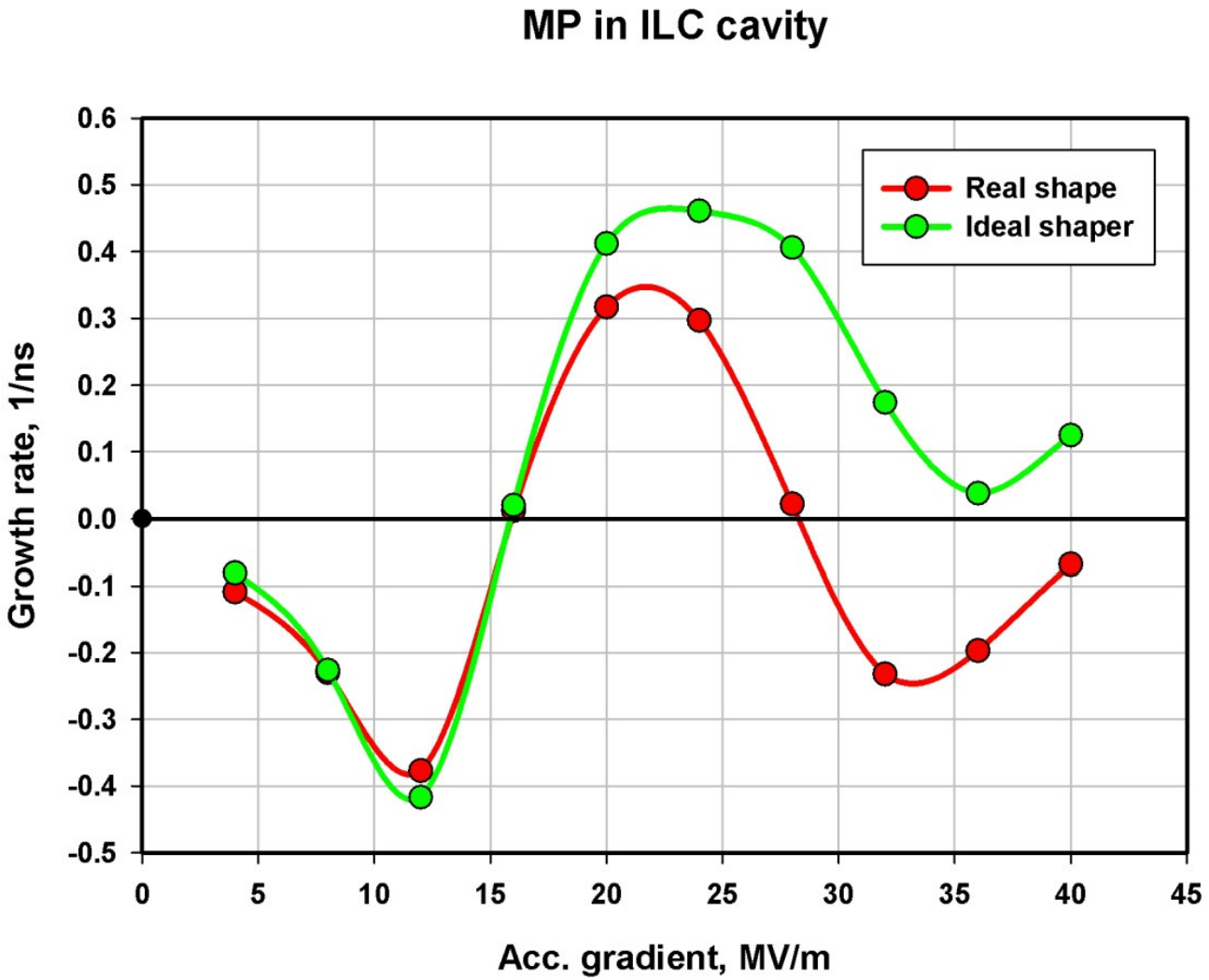
Particles after 8 ns:



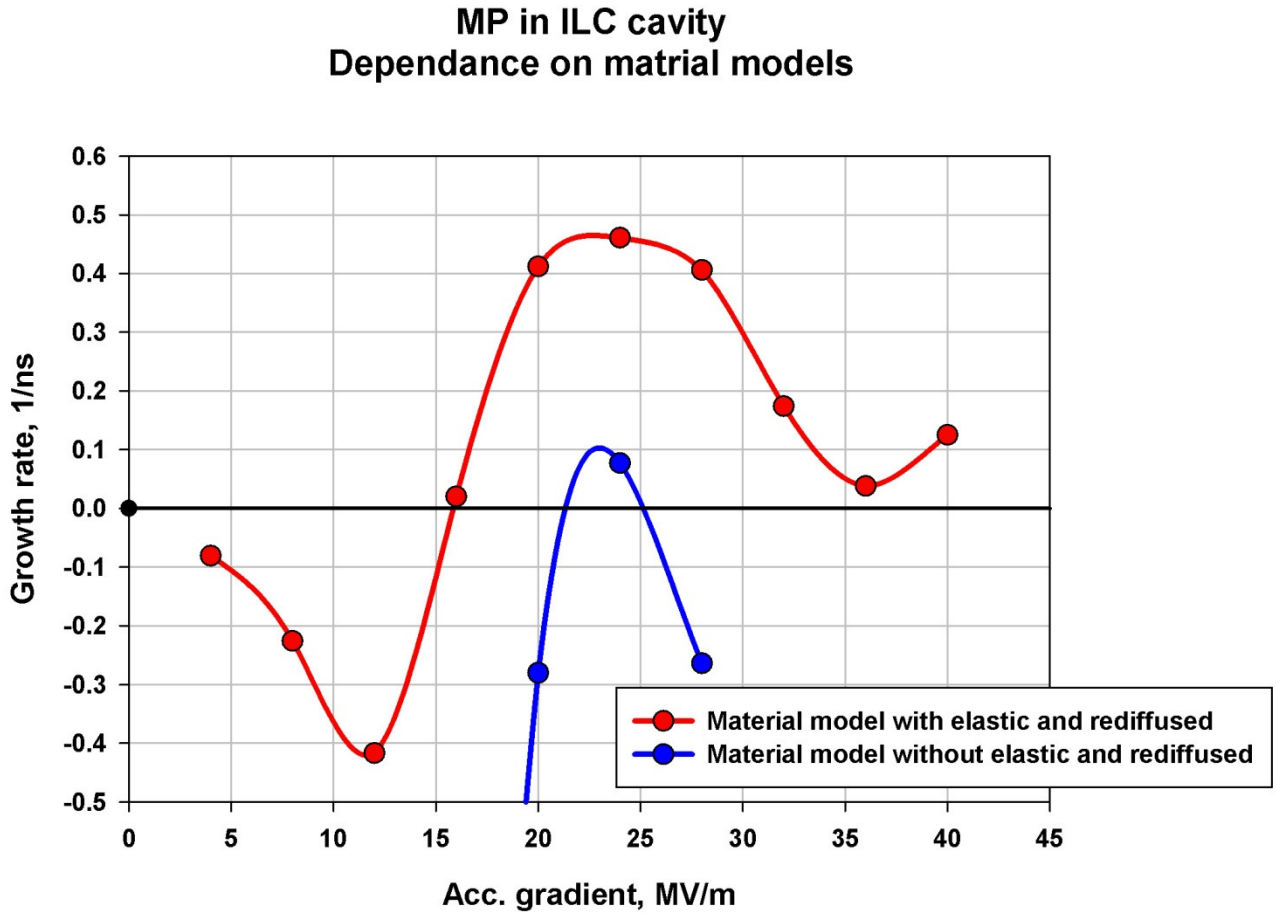








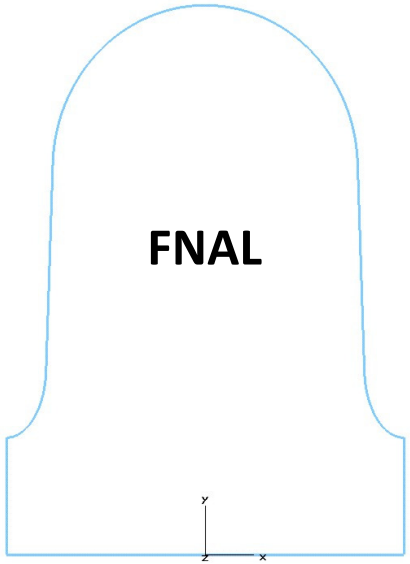
Experiment: soft MP exists in region ~20-25 MV/m

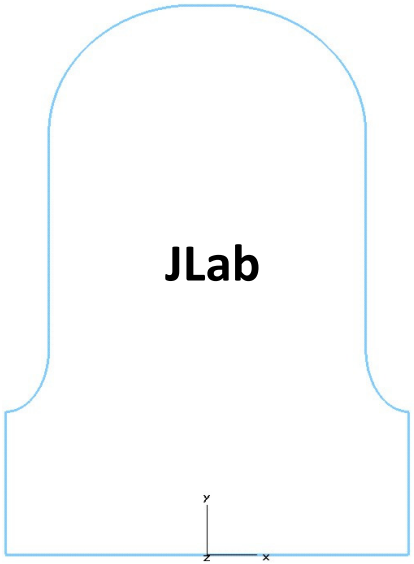


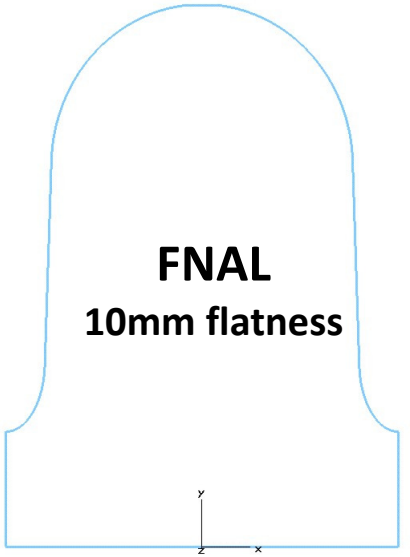
Conclusions:

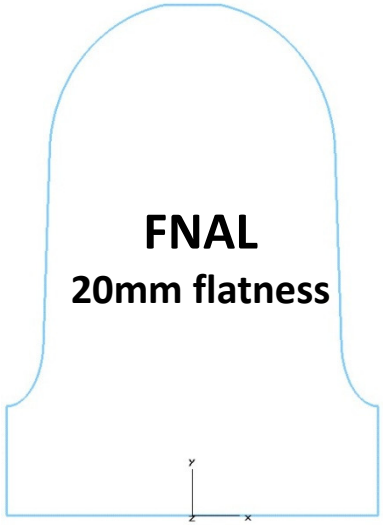
1. Elastic and reduffused electrons change drastically situation and have to be included into the model. But we have no this kind information for niobium.
2. Other codes can not see MP because they do not include elastic and rediffused electrons.

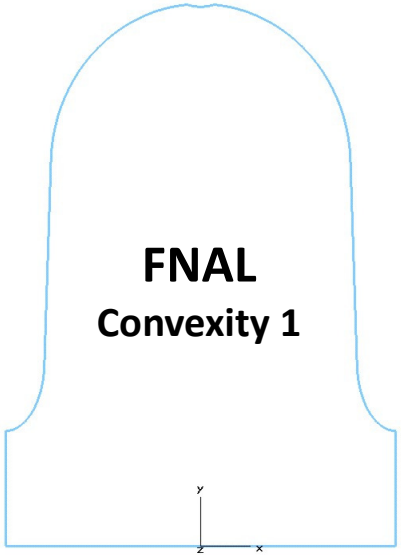
Simulation of 650MHz b=0.61, simulated shapes:

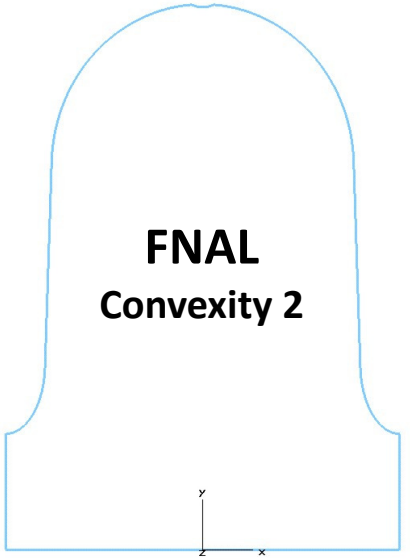


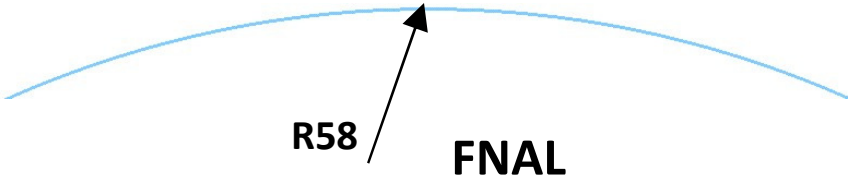




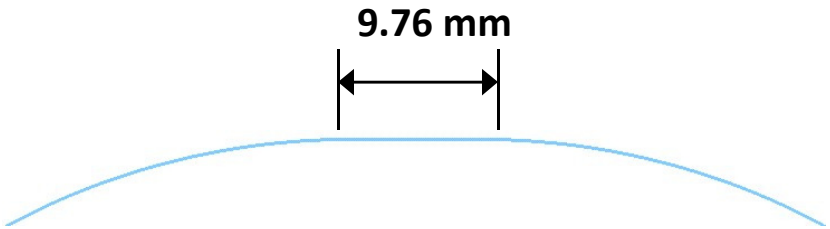




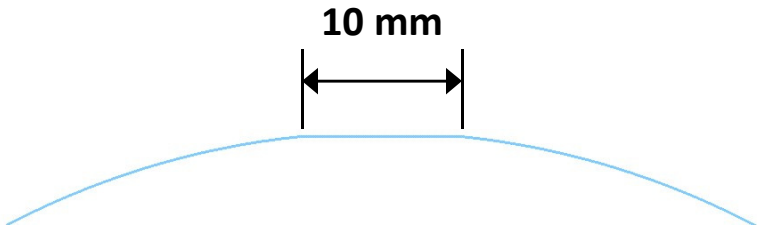




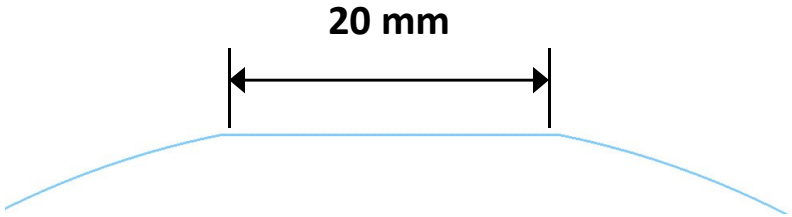
FNAL



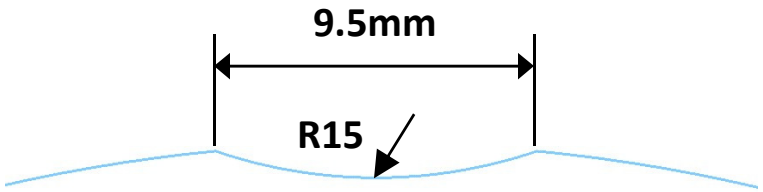
JLab



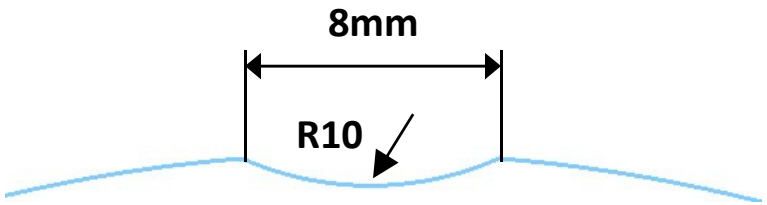
FNAL, 10mm fatness



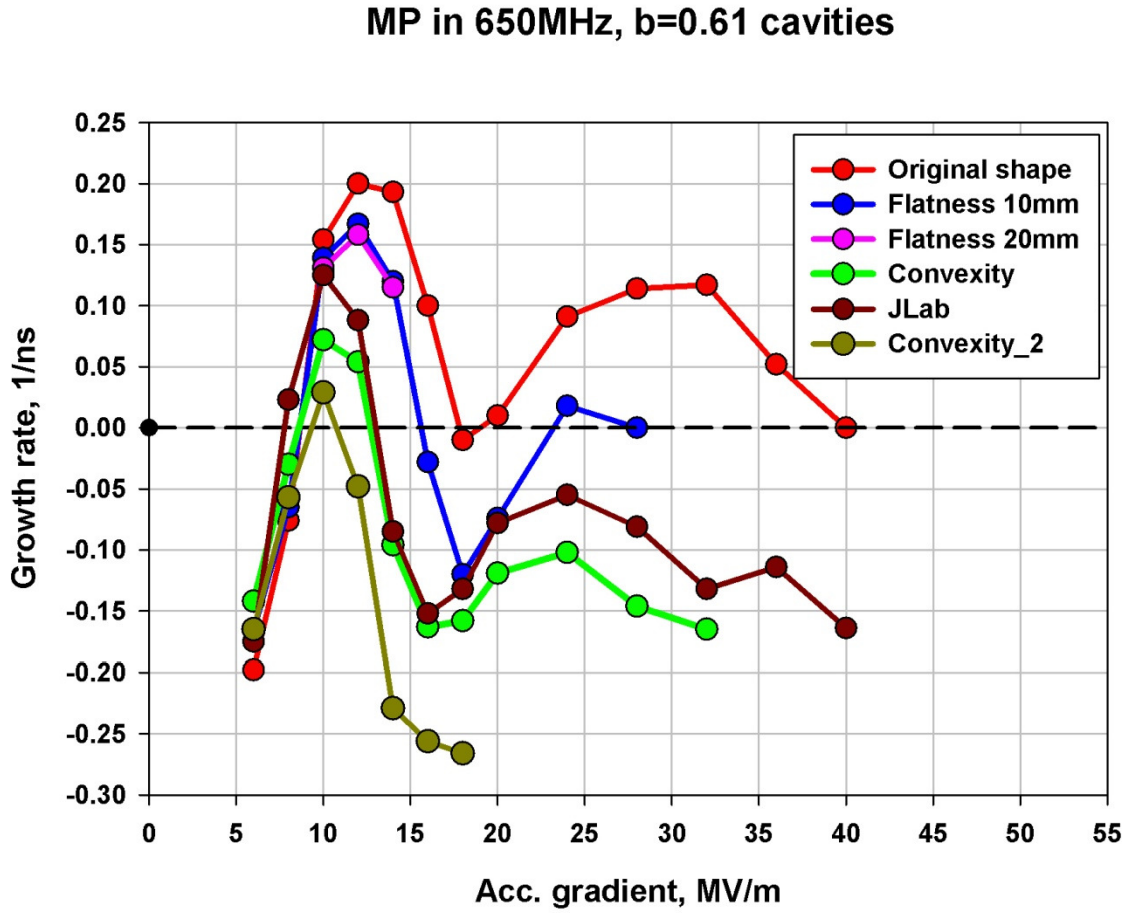
FNAL, 20mm flatness



Convexity 1



Convexity 2



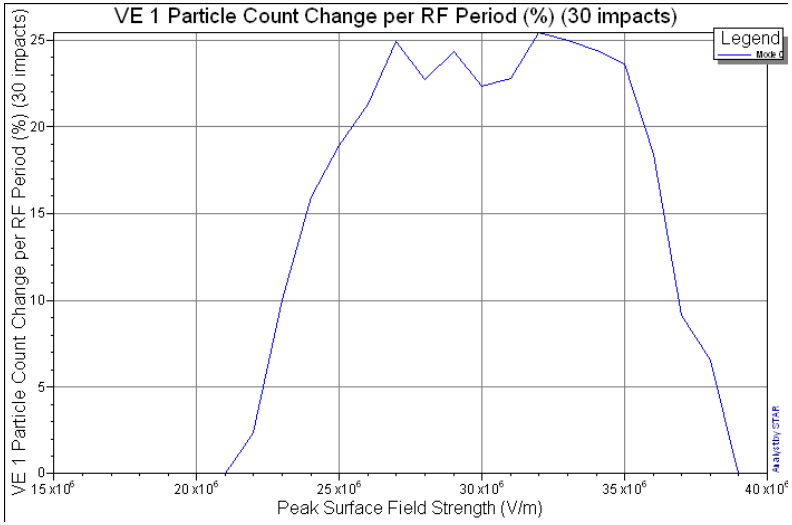
Mesh: min. 0.124mm, max. 0.251mm

Convexity does not change parameters of cavities: max. fields, Q, R/Q, etc.

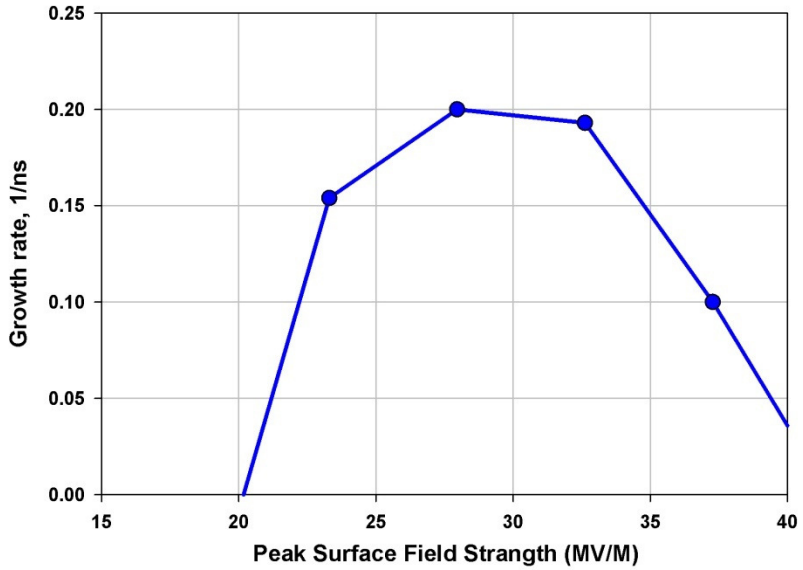
But it suppresses MP significantly

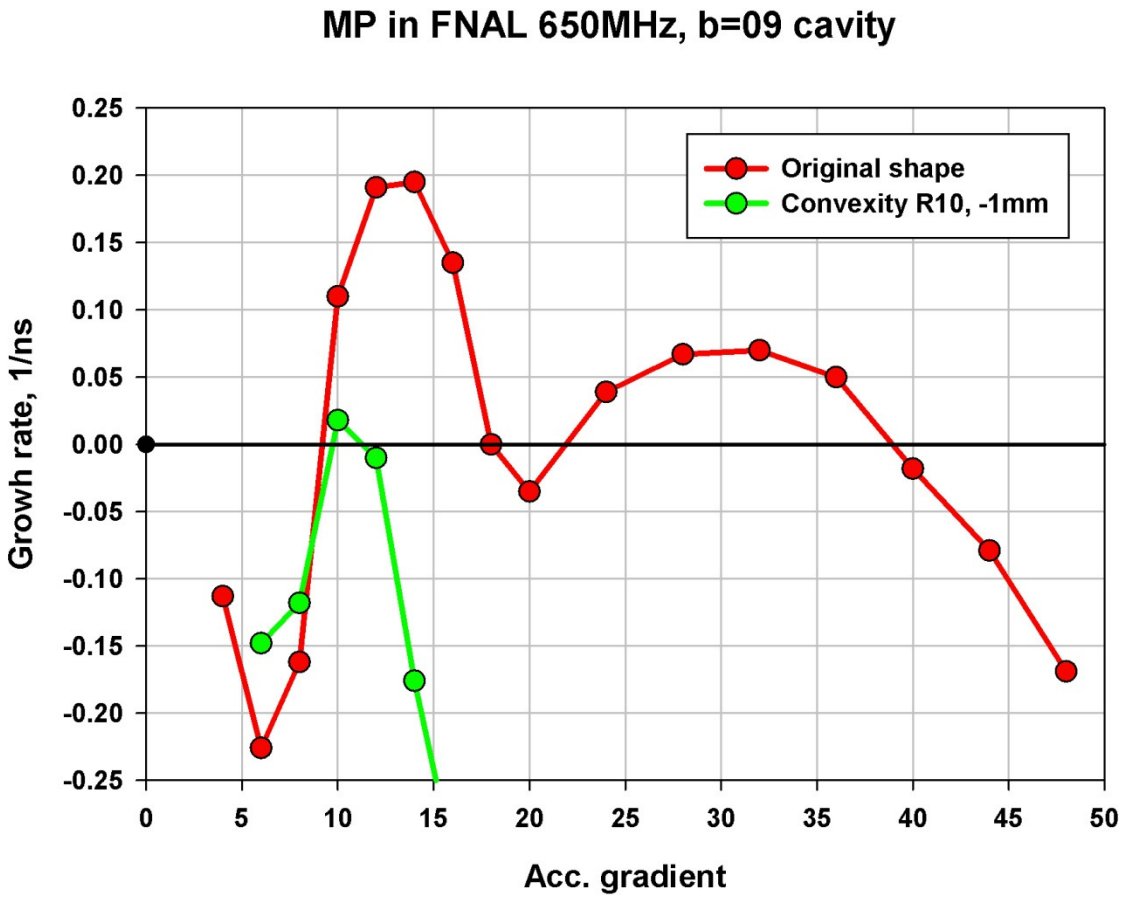
New 2D "Analist" finally found MP after including elastic and rediffused electrons in the model

Analyst Simulation



CST Simulation




MP in FNAL 650MHz, b=09 cavity
Original shape
Convexity R10, -1mm
Growh rate, 1/ns
Acc. gradient
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
0
5
10
15
20
25
30
35
40
45
50

Suggestion:

To conceder a possibility to make cavity with convexity.

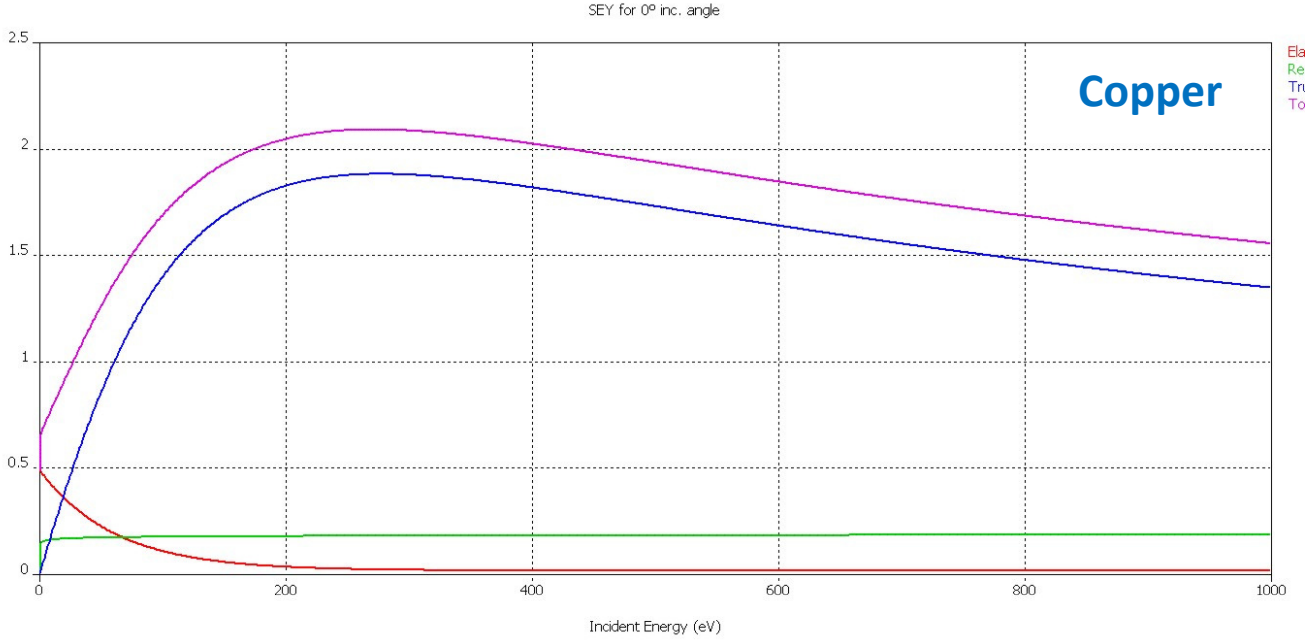
Conclusion:

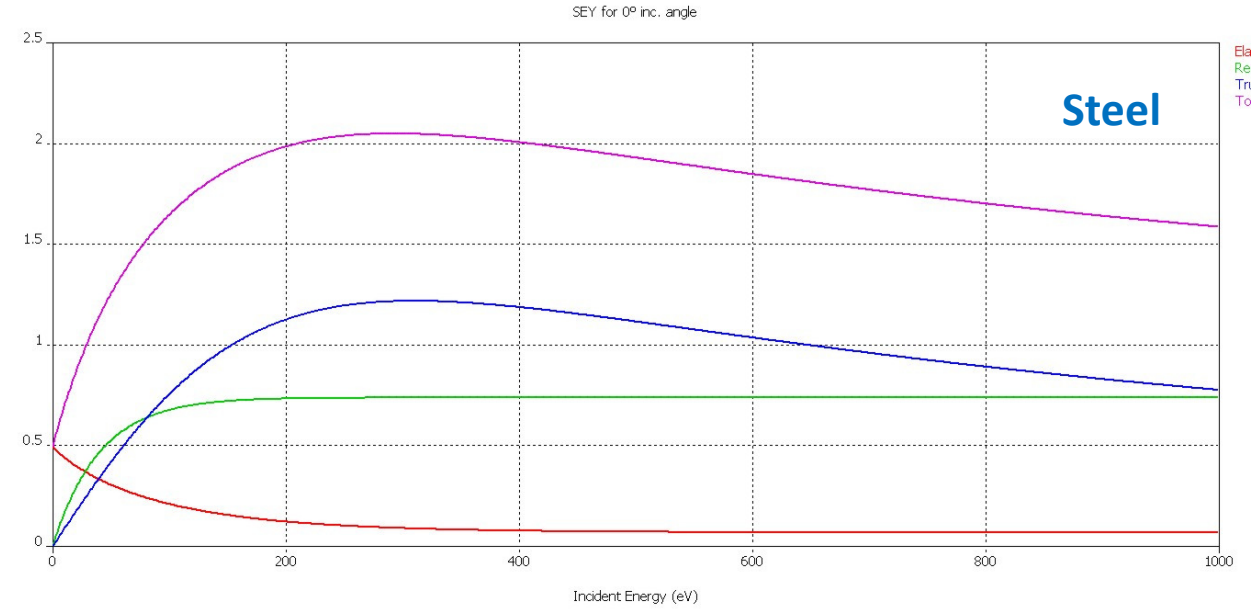
1. **It seems we can trust CST:**
   - **a) we found mesh size which provide convergence**
   - **b) CST and Analyst give similar results**
   - **c) CST predict MP in ILC in region when it is observed experimentally**

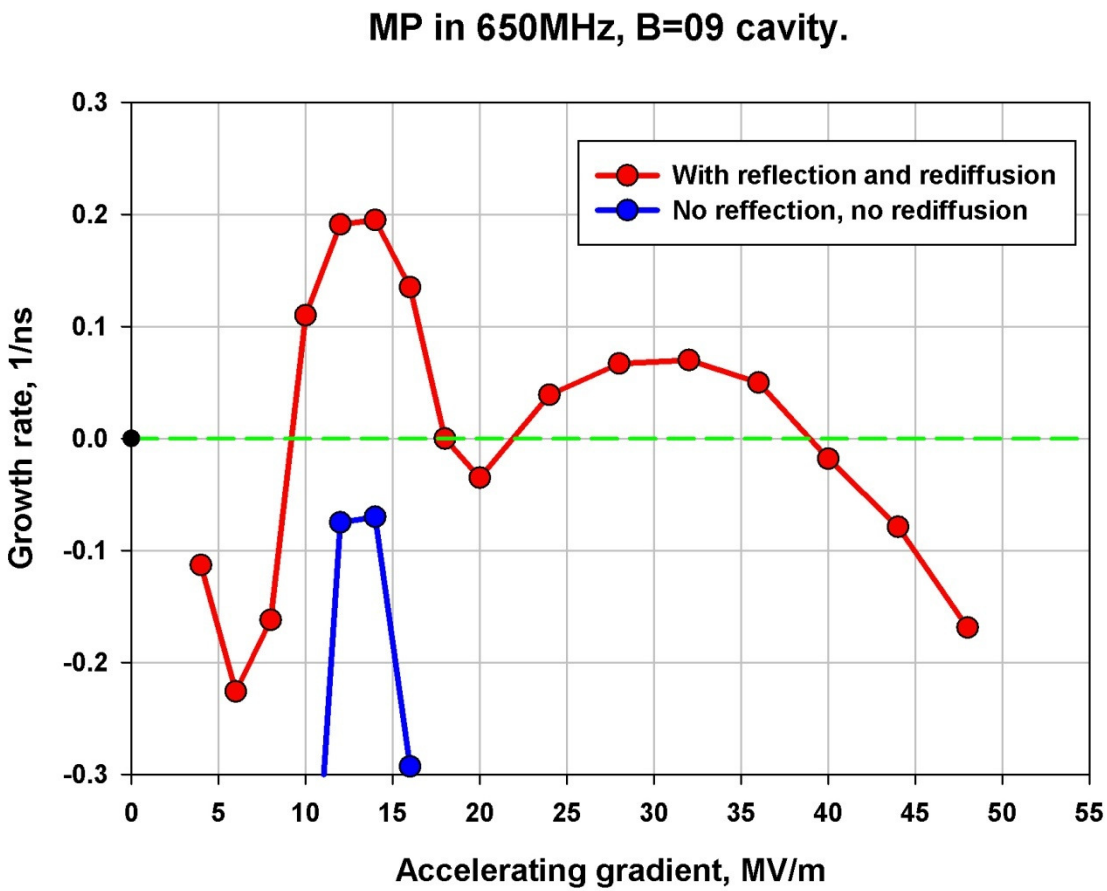
2. **MP is possible in 650 MHz cavities**

3. **Small convexity suppress MP.**

Backup


SEY for 0º inc. angle
Copper
Ela
Re
Tri
To
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
Incident Energy (eV)


SEY for 0º inc. angle
Steel
Ela
Re
Tri
To
2.5
2
1.5
1
0.5
0
0
200
400
600
800
1000
Incident Energy (eV)



Mesh: min. 0.125mm, max. 0.251mm